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Report No. 8926-138

Material - Steel - Stainless - Type 422M
United States Steel Corporation 12MoV

Resistance and Fusion Weld Strengths

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Abstract:

The resistance and fusion weld strengths of United States Steel Corporation 12MoV stainless steel, a modified 12% chromium steel, were determined with sheet material which was heat treated by austenitizing at 1850°F., air cooling and tempering at 900°F. for 4 hours, and welding. Resistance welded 0.008, 0.016, 0.025 and 0.050 inch thick sheets were generally capable of meeting Specification MIL-W-6858 tensile-shear strength requirements with tensile shear-cross tension ratios of about 0.20 when welded in the full heat treated condition (220,000 psi yield strength). The joint efficiency of fusion welded sheets which were welded in the fully heat treated condition was found to be about 80 per cent.

Reference: Giuntole, A., Bergstedt, P. W., Turner, H. C., "Resistance and Fusion Welding of U.S.S. 10MoV (422M) Stainless Steel," General Dynamics/Convair Report MP 58-096, San Diego, California, 30 October 1958, (Reference attached).

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RESISTANCE AND FUSION WELDING OF U.S.S. 12 MoV (422m) STAINLESS STEEL

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Report No. MP 58-096
Resistance and Fusion Welding
Of U.S.S. 12 MoV (422m) Stainless
Steel

INTRODUCTION

Materials for future airframes will be required to maintain adequate mechanical properties at elevated temperatures. This will preclude the use of mechanical fasteners in various areas in the interest of weight savings and design considerations. Two methods of replacing mechanical fasteners are fusion and resistance welding.

U.S.S. 12 MoV is one of a class of 12% chromium stainless steels modified by different alloying elements to avoid a brittle failure region extending from 700°F. to 900°F. inherent in the straight 12% chromium stainless steels. These alloying modifications also tend to increase the elevated temperature mechanical properties of the steels.

The 12 chromium stainless steels-straight or modified-are air hardening, particularly in sheet form. This hardening characteristic poses welding difficulties.

OBJECT

To determine the mechanical properties of fusion and resistance welded U.S.S. 12 MoV (422m) stainless steel.

CONCLUSIONS

1) Resistance welded U.S.S. 12 MoV met the Mil-W-6858 Specification for tensile-shear strength except for the gage combination of .025-.050.

2) Where cross-tension strength was determined, the indications were that cross-tension to tensile-shear ratios of 0.20 are possible with resistance welded U.S.S. 12 MoV (422m) stainless steel.

3) Increasing temperature decreased tensile-shear and cross-tension to tensile-shear ratios for resistance welded U.S.S. 12 MoV (422m) except for the .025-.050 combination where tensile-shear strength increased with increasing testing temperature.

4) The 0.016" gage material fusion welded to itself attained 78% of the room temperature ultimate strength of the fully heat treated unwelded parent material.

5) The 0.050" gage material fusion welded to itself attained 81% of the room temperature ultimate strength of the fully heat treated unwelded parent material.

6) Fusion weld joint strength and ductility decreased with increasing test temperature.

MATERIAL

All sheets used for this test were supplied by the United States Steel Company from their heat number 18833. The material that was tested included 0.008, 0.016, 0.025 and 0.050 inch thicknesses.

PROCEDURE

Strips 1" x 4" for tensile-shear specimens were taken from sheets of all thicknesses listed above. Cross-tension specimens 1" x 3" with 3/8" holes drilled on 2" centers were taken from the 0.016, 0.025, and the 0.050 sheets. In addition panels 4" x 12" for fusion welding were taken from the 0.016 sheet and the 0.050 sheet.

All the specimens were austenitized at 1850°F. for 15 minutes, in a production furnace, and air cooled. Tempering at 900°F. for 4 hours was done in a laboratory re-circulating air furnace.

The welding was done by the Manufacturing Research and Development. Their welding procedures and combinations welded are shown in Appendix A.

After welding, two tensile shear specimens from each resistance welded combination and two specimens from the fusion welded 0.050" sheet were re-tempered at 900°F. for 4 hours in a laboratory re-circulating air furnace.

Sections for microscopic examination were taken from each welded combination. Tukon hardness readings were made on the .025-.025 and .050 to .050 resistance welded material and the 0.050 fusion welded material.

The mechanical properties were determined using a Baldwin Universal Testing Machine. The heat source for the elevated temperature test was a re-circulating air furnace placed in the machine.

RESULTS

Table I lists the tensile-shear and cross-tension strength at various temperature of all the combinations resistance welded. Table II shows the mechanical properties at various temperatures of fusion welded .016" and .050" sheet. Hardness traverse readings are listed in Table III.

Figure 1 shows the effect of testing temperature on the tensile-shear and cross-tension strength of .025" material resistance welded to .025" material. Figure 2 shows the effect of testing temperature on the tensile-shear and cross-tension strength and the cross-tension to tensile-shear ratio of .025" sheet resistance welded to 0.050" sheet. Also shown in Figure 2 is the effect of temperature on the cross-tension strength of .016" sheet resistance welded to .050" sheet. The effect of temperature on the tensile-shear and cross-tension strength and the cross-tension to tensile-shear ratio of .050" sheet resistance welded to .050" sheet is shown in Figure 3. Figure 4 shows the effect of temperature on the ultimate strength and elongation on both the .016" sheet fusion welded to itself and the .050" sheet fusion welded to itself.

RESULTS (Continued)

Cross sections of the .050" sheet resistance welded to itself, the .025" sheet resistance welded to the .050" sheet, and the .050 " sheet fusion welded to itself are shown in Figures 5 and 6, respectively.

DISCUSSION

All resistance welded joints, except for the 0.025" sheet welded to the 0.050" sheet, met the tensile-shear requirements of Mil-W-6858. There was no apparent reason why the 0.025" to 0.050" combination should not have met the requirements of Mil-W-6858.

The tensile-shear strength of both the 0.025" sheet welded to itself and the 0.050" sheet welded to itself and the cross-tension strength of the 0.050" sheet welded to itself decreased with increasing temperature. The cross-tension to tensile-shear strength ratio of the 0.050" sheet welded to itself was relatively un-affected by temperature.

In the instances where unlike thicknesses were welded to each other the results appeared to be quite different. The tensile-shear strength of the 0.025" sheet welded to the 0.050" sheet increased with testing temperature. The cross-tension strength and cross-tension to tensile-shear strength ratio decreased with temperature. At both room temperature and 1000°F. there was little difference in the cross-tension strength of the .016" sheet welded to the 0.050" sheet; an increase in the cross-tension strength was noticed at the intermediate temperature. The tensile-shear strength of the 0.008" sheet welded to the 0.016" sheet appeared to be relatively un-affected throughout the temperature range tested. However, a tendency to drop off at around 1000°F. was noticed.

When some of the tensile-shear specimens were re-tempered in a furnace at 900°F. for 4 hours, an increase of room temperature tensile-shear strength was observed except when the 0.050 " sheet was welded to itself.

This points to the fact that probably all the welds except the 0.050" sheet welded to itself received insufficient temper in the machine. If this is the case, it would account ~~in part~~ for the erratic behavior of the resistance welds.

The 0.016" sheet fusion welded to itself and the 0.050" sheet fusion welded to itself attained 78% and 81%, respectively, of the unwelded fully heat treated ultimate strength of the parent metal at room temperature. Furnace tempering the 0.050" sheet fusion welded to itself at 900°F. for 4 hours resulted in a recovery of 84% of the unwelded fully heat treated ultimate strength of the parent metal. These results seem to indicate that a 100% fusion weld efficiency cannot be attained unless a full heat treatment is employed after the welding operations. However, further testing would be needed to definitely determine this.

DISCUSSION (Continued)

The elongation of the fusion welded specimens was approximately 80% lower than the elongation for the parent material. A re-temper in a furnace at 900°F. for 4 hours did not improve the welded ductility.

Increasing temperature resulted in decreasing ultimate strength and elongation. The failures occurred away from the weld and appeared to take place at the edge of the heat affected zone adjacent to the parent material. (See Figure 6). This is the area where the lowest hardness readings were observed.

NOTE: The data from which this report was written are recorded in Structures and Materials Laboratory Notebook No. 965.

TABLE I - TENSION SHEAR AND CROSS TENSION STRENGTH OF SINGLE SPOTWELDS IN FULLY HEAT TREATED 422M STAINLESS STEEL OF VARIOUS GAGE SIZES AT VARIOUS TEMPERATURES

SHEET COMBINATION (IN.)	TEST TEMPERATURE (°F)	TENSION-SHEAR (LBS)			AVE.	CROSS-TENSION (LBS)			AVE
.008 - .016*	R.T.	375	365		370				
.008 - .016	R.T	255	250	280	261.6				
" "	750	220	310	340	290.0				
" "	1000	240	210	210	220.0				
.025 - .025*	R.T.	1060	1070		1065				
.025 - .025	R.T.	988	836	926	917				
" "	750	710	784	705	733				
" "	1000	426	580	600	53[illegible].3				
.025 - .050*	R.T.	1170	1170		1170				
.025 - .050	R.T.	650	770		710	250	240	240	243.3
" "	750	588	650	1016	751	220	230	234	228
" "	1000	888	780	756	808	156	144	136	1[illegible]5.3
.050 - .050*	R.T.	3600	3200		3400				
.050 - .050	R.T.	3930	3740	3500	3723	889	705	863	5[illegible]7
	750	3240	3180	3200	3207	566	650	[illegible]88	634.6
	1000	2160	2400	2130	2230	514	526	530	523.[illegible]
.016 - .050	R.T.					133	151		142
" "	750					344	130	132	202
" "	1000					160	128	114	134

* SPECIMENS WELDED AS PER SCHEDULE AND FURNACE TEMPERED 900°F FOR 4 HOURS.
ALL OTHER SPECIMENS WERE AS WELDED

TABLE II - MECHANICAL PROPERTIES OF FUSION WELDED FULLY HEATTREATED 422M STAINLESS STEEL AT VARIOUS TEMPERATURES

.016" GAGE FUSION BUTT WELDED TO .016" GAGE

TEST TEMPERATURE (°F)	.2% FTY KSI	FTU KSI	ELONG % IN 2"	
R.T.(1)	196.9	252.7	SEE NOTE 4	
	198.1	253.0	"	
	197.5	252.9		AVE
R.T.(2)	187.7	202.6	1.5	
	188.0	192.8	3.0	
	187.8	197.7	2.3	AVE
750(2)		160.7	1.5	
		161.3	2.0	
		160.3	2.0	
		160.8	1.8	AVE
1000(2)		45.5(5)	0	
		137.7	0.5	
		155.5	1.0	
		146.6	0.7	AVE

.050" GAGE FUSION BUTT WELDED TO .050" GAGE

TEST TEMPERATURE (°F)	.2% FTY KSI	FTU KSI	ELONG % IN 2"	
R.T.(1)	187.9	248.5	10.5	
	185.8	250.6	6.5	
	186.8	249.5	8.5	AVE
R.T.(3)	187.4	214.1	2.0	
	192.9	206.7	2.0	
	182.4	209.9	2.0	
	187.6	210.2	2.0	AVE
R.T.(2)	188.5	197.3	2.0	
	188.5	202.2	1.5	
	188.5	199.8	1.7	AVE
750(2)		175.1	0.5	
		178.1	1.0	
		162.2	0.5	
		171.8	0.4	AVE
1000(2)		133.0	0	
		129.4	1.5	
		143.0	0	
		135.1	0.5	AVE

1. PARENT METAL PROPERTIES
2. PROPERTIES OF MATERIAL AS WELDED AND POST HEATED AT 450°F IN WELDING UNIT
3. MATERIAL WELDED AS IN (2) AND FURNACE TEMPERED AT 900°F FOR 4 HOURS
4. SPECIMENS BROKE IN THREE PIECES; UNABLE TO DETERMINE % ELONGATION
5. NOT AVERAGED

TABLE III - KNOOP HARDNESS AND APPROXIMATE R_c READINGS OF RESISTANCE WELDED 0.025" TO 0.025" SHEET AND 0.050" TO 0.050" SHEET AND FUSION WELDED 0.050" TO 0.050" SHEET

HARDNESS READING (1KG. LOAD) LOCATION		RESISTANCE WELD 0.025" TO 0.025"			RESISTANCE WELD 0.050" TO 0.050"			FUSION WELD 0.050" TO 0.050"	
		TUKON	Rc(APPROX)		TUKON	Rc(APPROX)		TUKON	Rc(APPROX)
PARENT METAL		565	51.4		507	48.2		557	51.0
		568	51.5		533	49.3		552	50.6
		568	51.5		511	48.0		562	51.2
		572	51.8						
	AVE	568	51.6	AVE	517	48.5	AVE	557	51.0
TRANSITION FROM PARENT METAL TO HEAT AFFECTED ZONE*		413	41		398	39.6		513	48.2
		417	41.2		392	[illegible]		486	46.4
		408	40.7		410	40.7		[illegible]	48.0
								507	47.9
	AVE	413	41	AVE	400	39.5	AVE	504	47.6
HEAT AFFECTED ZONE		549	50.5		515	48.8		608	53.7
		558	51.0		514	48.8		595	52.2
		558	51.0		541	50.0		595	53.0
	AVE	555	50.8	AVE	523	49.2	AVE	600	53.0
WELD NUGGET		551	50.5		538	49.7		632	55.1
		587	52.7		544	50.1		626	54.7
		581	52.2		533	49.5		611	54.0
		568	51.4					611	54.0
	AVE	576	52	AVE	535	49.8	AVE	620	54.5

* BLACK ZONE SHOWN IN FIGURES 5&6. THIS ZONE ALSO EXISTS FOR THE 0.025" TO 0.025" RESISTANCE WELD

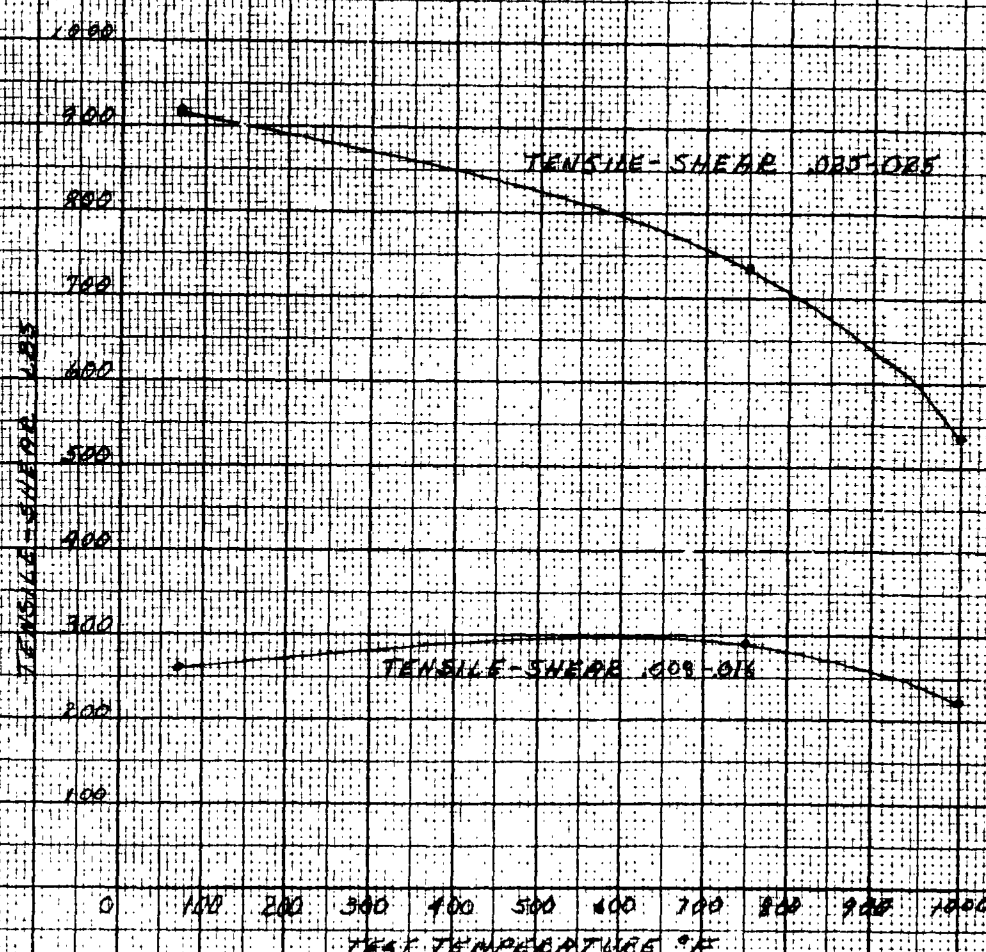

FIG 1 - EFFECT OF TEMPERATURE ON THE TENSILE-SHEAR STRENGTH OF .025" THICK 422M SPOT-WELDED TO .025" THICK 422M AND .009" THICK 422M SPOTWELDED TO .016" THICK 422M

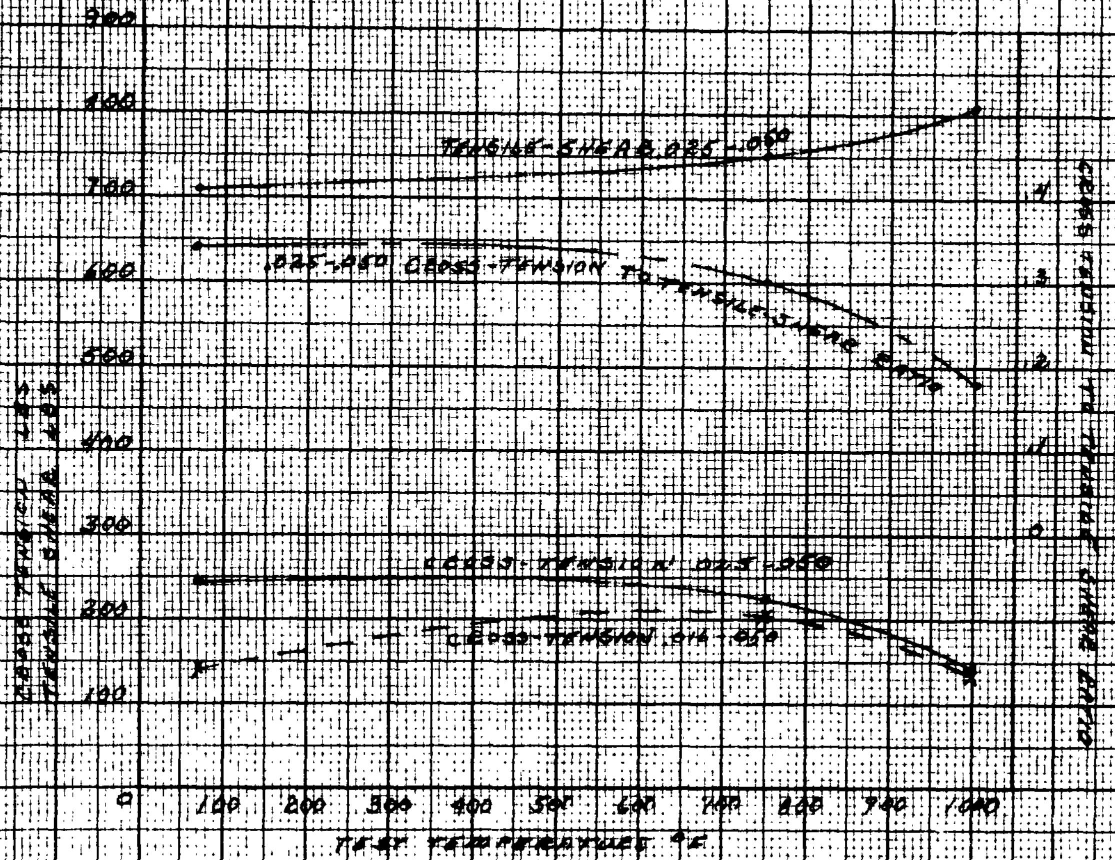

FIG 2 - EFFECT OF TEMPERATURE ON THE TENSILE SHEAR STRENGTH, CROSS TENSION STRENGTH, AND THE CROSS TENSION TO TENSILE SHEAR RATIO OF .025" THICK 422M SHEET SPOT WELDED TO .050" THICK SHEET OF 422M, AND ON THE CROSS TENSION STRENGTH OF .014" THICK 422M SHEET SPOT WELDED TO .050" THICK SHEET OF 422M

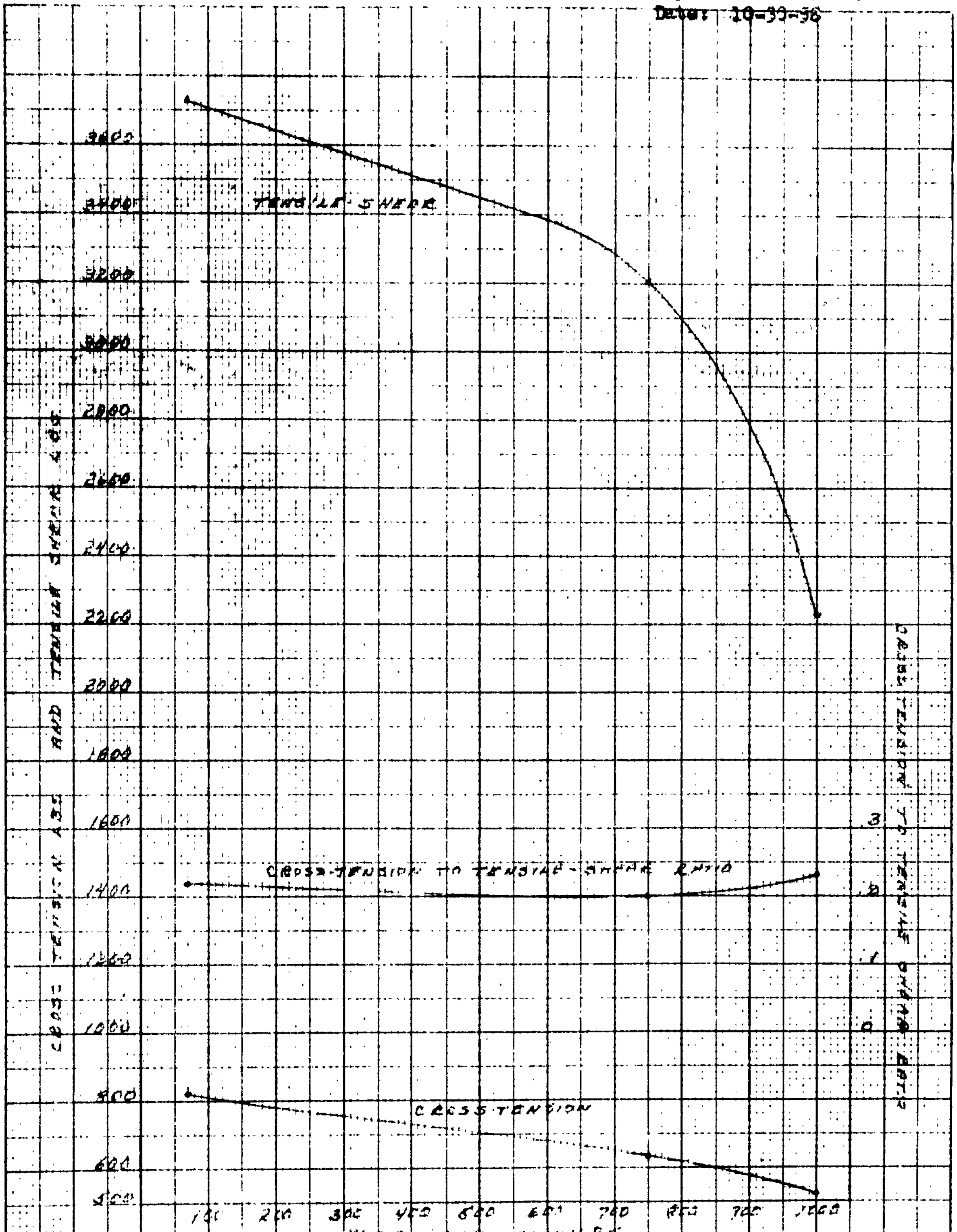

FIG. 3 EFFECT OF TEMPERATURE ON THE CROSS TENSION STRENGTH, TENSILE SHEAR STRENGTH, AND THE CROSS TENSION TO TENSILE SHEAR RATIO OF .050" THICK SHEET OF [illegible] SPOTWELDED [illegible] SHEET OF [illegible]

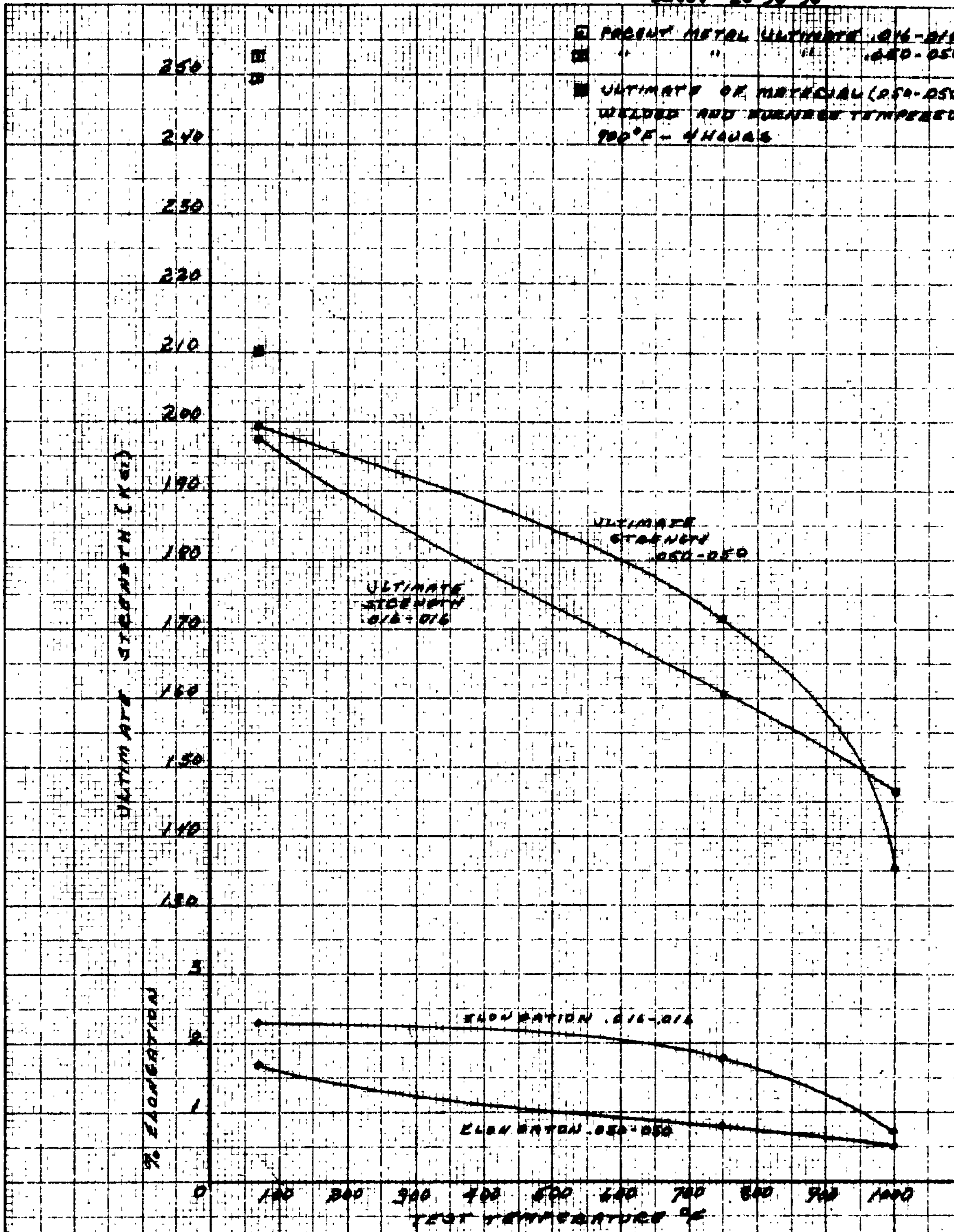

FIG 4 - EFFECT OF TEMPERATURE ON THE ULTIMATE STRENGTH AND ELONGATION OF FUSION BUTT WELDED .016" THICK SHEET OF 422M TO AN .016" THICK SHEET OF 422M AND AN .050" THICK SHEET OF 422M BUTT FUSION WELDED TO AN .050" THICK SHEET OF 422M

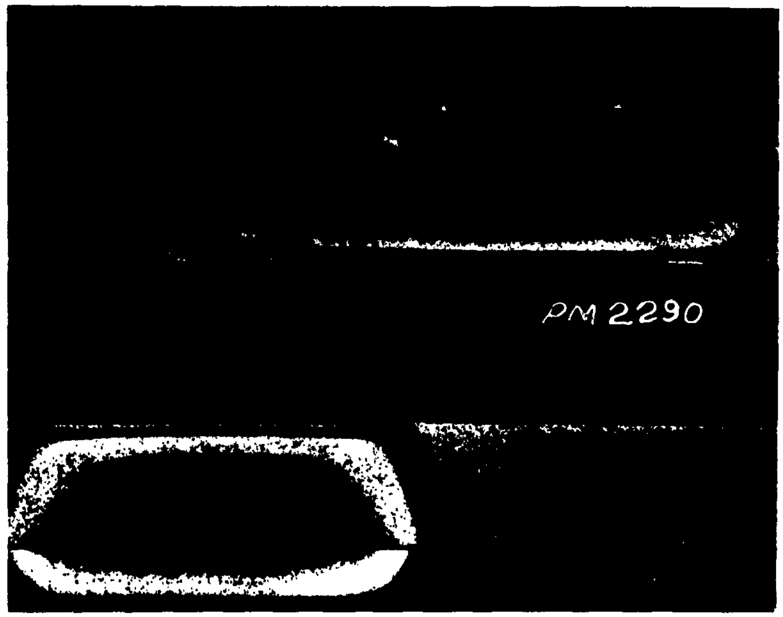

Figure 5 Top - .050" - .050". Resistance Weld
Bottom - .025" -.050" Resistance Weld

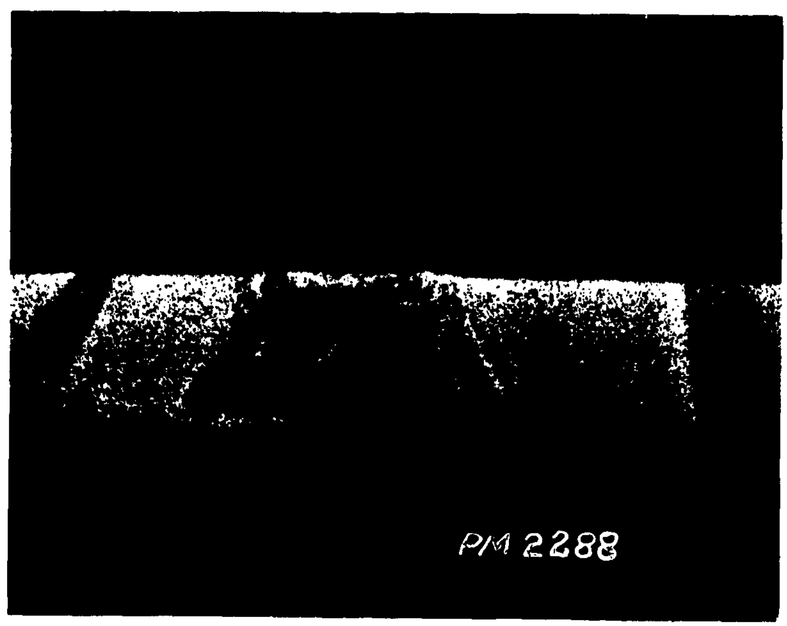

Figure 6 Fusion Weld in The 0.050" Sheet

APPENDIX "A"

WELDING MACHINE SETTINGS

RESISTANCE WELDING

All resistance welding was performed on a Sciaky three phase machine: 100KVA with the decatron digital counter control.

The welding procedure was to establish a nugget free from crack and porosity, with a diameter based on the formula 4 T. Penetration was controlled as close as possible with minimum and maximum limits being 30-80% respectively.

.008" - .016" - Investigation revealed these optimum weld conditions:

Electrode Material	RWMA Class III
Electrode Design	5/8" restricted diameter 6" radius dome
Weld Time	2 cycles
Electrode force	400 pounds
Weld Current	5400 amps
Quench time	30 cycles
Temper time	6 cycles
Temper current	3200 amps

.025"- .025" - Investigation revealed these optimum weld conditions:

Electrode Material	RWMA Class III
Electrode Design	5/8" restricted diameter 6" radius dome
Weld Time	4 cycles
Weld current	9500 amps
Electrode Force	1500 psi
Quench time	90 cycles
Temper time	4 cycles
Temper current	3800 amps.

.025" - .050" - Investigation revealed these optimum weld conditions:

Electrode Material	RWMA Class III
Electrode Design	5/8" restricted Dia. 6" radius dome
Weld Time	5 cycles
Weld Current	1500 amps.
Electrode Force	2000 psi
Quench time	100 cycles
Temper Time	1 cycle
Temper current	9000 amps.

APPENDIX (CONTINUED)

.050" - .050" - Investigation revealed these optimum weld conditions:

Electrode Material	RWMA Class III
Electrode Design	5/8" restricted dia. 6" radius dome
Weld Time	7 Cycles
Weld Current	11000 amps.
Electrode Force	2000 psi
Quench Time	90 cycles
Temper time	6 cycles
Temper current	2000 amps.

.016" - .050" - Investigation revealed these optimum weld conditions:

Electrode Material	RWMA Class III
Electrode Design	5/8" restricted dia. 6" radius dome
Weld Time	4 cycles
Weld Current	13000 amps.
Electrod Force	2000 psi
Quench	90 cycles
Temper Time	4 cycles
Temper Current	2600 amps.

FUSION WELDING

Fusion welding was performed on a mechanized weld fixture located in in Bldg. 1 of Plant II.

The material as received from the Engineering Test Lab. was distorted from the heat treat. The edges required a shear to produce adequate alignment when clamped in the weld fixture. Initial welds were made on a standard steel grooved backup bar plumbed to provide adequate atmospheric protection. The weld exhibited a crack running the full length of the weld in the area of the speed line. The standard backup bar was replaced with a copper bar incorporating integral heating units. Butt welds were made with no addition of filler wire at temperatures ranging from 250°F. - 500°F. No evidence of cracking occured at these temperatures however, a problem of warpage of the .016" material did occur at the higher temperatures making welding difficult.

The following machine settings produced the most satisfactory results:

Material	422 M Steel .052"
Amps	55
Volts	9
Speed	15
Torch gas	15 Argon
Backup Shield Gas	15 Argon

APPENDIX (CONTINUED)

Electrode Type & Design	1/16" 1% thoriated tungsten, pointed
Joint Design	Square Butt
Pre & Post heat	450°F.
Material	422 M Steel .016"
Amps.	16
Volt	9
Speed	20
Torch Gas	16 Argon
Backup Shield Gas	16 Argon
Electrode Type & Design	.040 1% thoriated tungsten, pointed
Joint Design	Square Butt
Pre & Post Heat	450°F.